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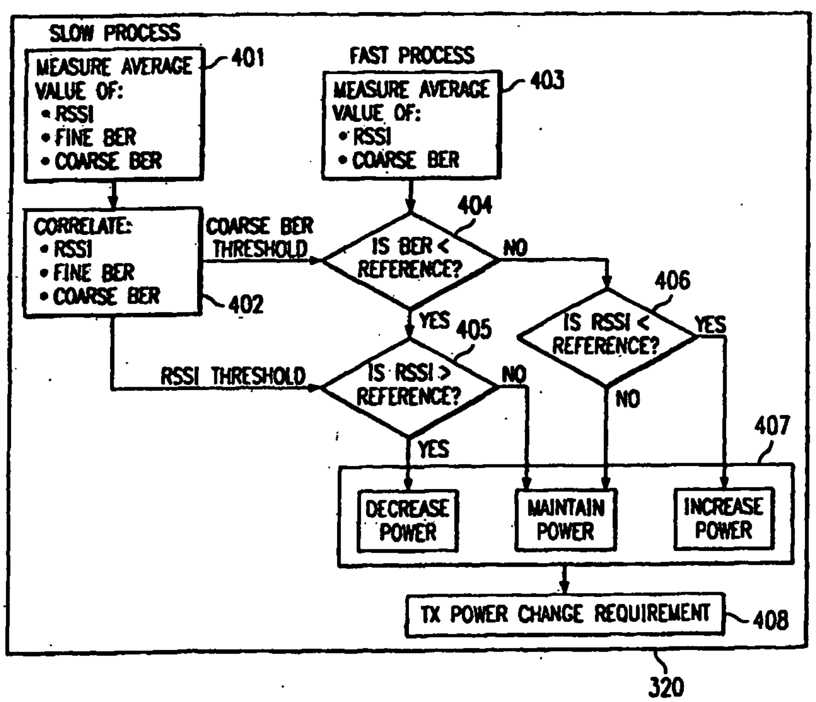
(54) Title: SYSTEM AND METHOD OF CONTROLLING CO-CHANNEL INTERFERENCE IN POINT TO POINT COMMUNICATIONS

(57) Abstract

Systems and methods for controlling the transmitter of a point to point transmitter/receiver pair to provide a substantially constant radiation contour are disclosed. According to a preferred embodiment of the present invention a point-to-point link performance characteristic, such as the bit error rate as experienced by the receiver, is established as a desired operating characteristic. However, as this operating characteristic may require substantial time to measure, other link attributes are also measured in order to provide more rapid determinations of required link adjustments required to achieve the desired performance characteristic. In the preferred embodiment both a coarse bit error rate and a receive signal strength are measured and correlated to the link performance characteristic in order to provide the more rapid determinations of required link adjustments.



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SYSTEM AND METHOD OF CONTROLLING CO-CHANNEL INTERFERENCE IN POINT TO POINT COMMUNICATIONS

TECHNICAL FIELD OF THE INVENTION

This invention relates to point to point systems and more specifically to a system and method for controlling the co-channel interference between a plurality of such systems.

BACKGROUND OF THE INVENTION

Transmission of radio signals over the air provides many advantages over other transmission media for communication systems. However, by their nature, radio wave transmissions cannot avoid co-channel interference when two or more radios operating at the same frequency are deployed in close proximity. This co-channel interference degrades the link performance. Accordingly, for a mass radio deployment in a given area, the system performance is interference limited.

Depending on the service requirement, unique solutions or schemes of controlling co-channel interference have been used. For example, mobile service providers often use the geometry and spatial separation of radiation structures to control co-channel interference through frequency reuse planning. Generally, cellular telephone service providers solve co-channel interference problems utilizing cell structures which separate frequencies into zones (sectors and/or cells) and/or into time domains (time bursts of a time division multiple access (TDMA) system).

For a mobile service utilizing code division multiple access (CDMA), the interference control technique generally uses intra and inter-cell power control of active user transmitted power instead of frequency reuse. Accordingly, at predetermined common points, such as the base station receiver, the mobile unit transmission power levels are controlled to have a common level of input so they interfere with each other equally and, therefore, each signal may be recovered from the received composite signal.

Point to point systems typically utilize microwave or extremely high frequencies and are highly directional, i.e., focused from a particular transmitter having a fixed location to a particular receiver having a fixed location, rather than being broadcast over a large area to be received by any receiver operating within that area. However, like any other radios, point to point systems will interfere with each other under some conditions, such as when multiple transmitter/receiver pairs are operating at the same frequency and deployed in close proximity or along a common azimuth. Directional antennas can control the radiation in some directions, and can thus remediate interference problems. However, such directional antennas typically cannot control all potentially interfering propagation of radio waves, such as those associated with antenna beam side lobes or over radiation of signals.

For example, with point to point applications if a transmitter is deployed it is simple to plot a contour of the resulting antenna beam. Typically every receive radio located within this

antenna beam, which is pointing at the transmitter if directional, will be able to receive the signal. Clearly, even with highly directional antennas, there will be areas covered by the transmit antenna beam which are not necessary for establishing communications with an intended receiver of a transmitter/receiver pair. These areas may be associated with a main beam extending beyond an intended receiver due to excessive transmit power, antenna beam side lobes, or the like. Accordingly, receivers associated with a second transmitter/receiver pair located within the contour of the antenna beam of this first transmitter, including its side lobes or its main beam shadow, will experience interference from this first transmitter.

In the past, the radio deployment of point to point transmitter/receiver pairs has been based on thin density deployment where every link is a special design and can thus avoid, or at lease remediate, the effects of receivers located within the antenna beam of a particular transmitter not associated with that receiver. However, situations which could benefit from high frequency systems, such as 20 to 40 GHz radio systems, deployed in mass in order to serve communication and data requirements of a metropolitan area exist. Accordingly, reliance on thin density deployment to provide interference remediation may not be acceptable.

It should be appreciated that the propagation loss for high frequencies, such as the aforementioned 20 to 40 GHz systems, varies a large amount depending on dynamic circumstances. For example, from a clear to rainy day the signal attenuation or signal loss variation could be as much as 40dB per km. Accordingly, in order to provide a sufficient signal to be received by the receiver of a transmitter/receiver pair during periods of extreme signal attenuation, the transmitter of the transmitter receiver pair may transmit at an increased power level, even during periods of reduced signal attenuation. This may result in a receiver associated with a different transmitter/receiver pair experiencing interference during these periods of reduced attenuation as the antenna beam contour of the transmitter of the first transmitter/receiver pair will be enlarged during this time where a constant transmit power level is used at the transmitter.

In prior art point to point systems, it is generally the practice to deploy a transmitter/receiver pair and adjust the transmit power level of the transmitter to allow for operation in the expected worst case circumstances. For example, depending upon the distance between the transmitter and receiver and the expected signal attenuation for predictable phenomena, such as precipitation, the transmitter power may be adjusted substantially greater than that required to provide suitable signal quality at the receiver during periods when no

precipitation is falling. As precipitation in most areas where such point to point systems are generally deployed is experienced significantly less frequently than periods of no precipitation, this fixed power adjustment for the worst case circumstances results in extended periods of over radiation of the signal. Likewise, as the fixed power level is adjusted for a worst case scenario, even when precipitation is experienced, the transmit power may be sufficiently high to over radiate the signal.

Accordingly, there exists a need in the art for a system and method which is adapted to adjust transmit power levels in order to maintain desired performance levels, i.e., reduce interference as experienced by radios to which the particular transmission does not pertain while maintaining signal quality at the radio, or radios, to which the transmission does pertain.

A further need exists in the art for a system and method for maintaining a minimum antenna beam contour so as to allow the dense deployment of communication systems, i.e., transmitter/receiver pairs. Accordingly, available spectrum would not be required to be unnecessarily broken up to service different communication links and, thus, each link, although closely spaced, may utilize a larger portion of the spectrum and, accordingly, all available bandwidth.

A still further need exists in the art for a system and method of dynamically adjusting communication parameters in order that dynamically changing circumstances may be compensated for. Dynamic adjustment of these communication parameter should advantageously take into consideration fault conditions and avoid undesired adjustment of the characteristics where a fault condition presents symptoms similar to that of a condition to be compensated for.

SUMMARY OF THE INVENTION

These and other objects, features and technical advantages are achieved by a system and method which provides for dynamic control of link parameters such as transmit power levels. In a preferred embodiment a power control means provides an antenna beam contour where the received signal level as experienced by the receiver of the transmitter/receiver pair is substantially constant. Accordingly, the transmit power compensates for the propagation loss, as dynamically experienced. Therefore, looking at the main beam pattern, the contour is constant under any compensated for conditions because the amount of power will be adjusted according to the present invention so that the receive power level and/or other measured communication parameter, and therefore the contour, is constant.

A preferred embodiment of the present invention utilizes a closed feedback loop in order to provide information regarding the level of the measured communication parameter as experienced by the receiver of the transmitter/receiver pair. Accordingly, when the communication parameter is measured by the receiver at a higher level, the system provides feedback to the transmitter in order to adjust the power down. Likewise, when the receive signal is measured by the receiver at a lower level, the system provides feedback to the transmitter in order to adjust the power up.

Preferably the receiver system operates to make the desired measurements and initially determines the requirement of a power level, or other transmission characteristic, adjustment. Accordingly, a very small bandwidth return signal path may be utilized by the feedback loop, while still providing a desired level of functionality. For example, the receiver may determine not only that a measured characteristic is low, but also may conclude that an adjustment is necessary to compensate for this measured characteristic and, in a very few reverse link control channel bits, communicate the determination to the transmitter. Accordingly, wasting of reverse channel bandwidth may be avoided by not providing the adjustment circuitry of the transmitter with information regarding each measurement made of the particular parameter or parameters.

Likewise, preferably the transmitter system operates to accept the feedback regarding power level adjustments from the receiver system and determines the type, amount and/or propriety of the requested adjustment. For example, through reference to a knowledge base containing historical information regarding the operation of the communication link, the transmitter system may determine that a particular power level adjustment should not be made.

Accordingly, undesired power level adjustments in response to fault conditions may be avoided.

The receive signal or link characteristics may be measured in many different ways at the receiver. For example, a receive signal strength (RSSI), signal to noise (S/N), carrier to interference (C/I), or similar measurements may be utilized. However, as it is anticipated that the present invention will be utilized in the high speed transmission of data, a preferred embodiment measures the performance of the link in transmitting information. Accordingly, link performance measurements, such as a bit error rate (BER) measurements, may be made and power levels adjusted to maintain these measurements at a constant level. For example, by keeping the bit error rate constant, then the receive signal should be constant.

The use of such measurements are ideal in many situations as this is a parameter of the product actually supplied to the subscriber or user of the system. Accordingly, not only is the system of the present invention adapted to provide dynamic adjustment of link parameters, such as transmission power, in order to reduce interference as experienced by other systems in a large scale deployment, but so too is the system able to consistently provide a particular performance level to the subscriber.

However, it shall be appreciated that adjustments based on performance characteristics may include complexities not associated with more simple power level measurements. For example, where a particular error rate is selected as acceptable, it may not be as straight forward as counting errors occurring in a particular time span as these selected error rates are typically very low. Therefore, it may require a substantial amount of time to actually measure the error rate. Such lengthy measurement periods may be too long for any feedback useful in making adjustments to the transmit power level in a timely fashion.

Accordingly, the preferred embodiment of the present invention also measures parameters which may be measured more quickly than the measurement of actual performance characteristics and makes a determination as to what the actual performance characteristics are. This allows the present invention to make quicker determinations as to the performance characteristics and, thus, adjust communications parameters before a sufficient time has transpired to actually experience the performance characteristics the measured parameters are indicative of. It should be appreciated that not only does the measurement of these parameters allow a quicker adjustment of the communications parameters, but they also allow for the

adjustment of the parameters before the actual performance characteristics are measurably degraded.

In order to provide a reference for the measured parameters with respect to the desired and actual performance characteristics, the preferred embodiment of the present invention, in addition to making the aforementioned parameter measurements, also determines the actual performance characteristics, i.e., performs the time intensive performance characteristic measurements throughout the measuring of parameters for instantaneous determination of power level adjustment. Thereafter, the more quickly measurable parameters are correlated with the actual performance characteristic in order to allow their more use in determining or predicting the actual performance characteristic.

Additionally, it is desired to override the power level adjustments when the system goes into a fault condition. For example, if the system is malfunctioning in such a way as to cause the measured performance characteristic to exhibit symptoms of a phenomena typically adjusted for, such as if a directional transmit antenna is not properly aligned with a corresponding receiving antenna, the feed back information could result in an undesired increase in transmission power levels.

Similarly, installation conditions may necessitate the overriding of power level adjustments. As previously mentioned, the difference in signal attenuation due to precipitation or other changing conditions may be on the order of 40 to 50 dB/km. However, for some directional radiation patterns, side lobes may be only 25 dB down. Accordingly, during installation, when it is intended that the main beam of the transmit antenna is to be pointed at and locked on the main beam of the receiving antenna, it is possible that instead main beam to side lobe or side lobe to side lobe communications may be established if the system did not operate to control power level increases during this time.

Accordingly, a preferred embodiment of the present invention includes analysis of the feedback information in order to override power level adjustments when in response to a condition other than that intended to be compensated for. For example, a temporary maximum power level may be established for installation and/or antenna adjustment purposes in order to prevent power level adjustments sufficient to allow establishing communications other than through the main antenna beams.

Moreover, as the system during normal operation will have available information such as typical operating transmit power levels, possibly including information with respect to the

durations or percentages of operating times such levels are utilized, the system may operate to detect fault conditions through referencing this information. Accordingly, if high transmission power levels are invoked based on a particular measured characteristic for a duration longer than that historically experienced, the system may operate to notify a technician of a possible fault and/or reduce transmission power levels to a predefined maximum determined not to cause excessive interference with neighboring components.

It should be appreciated that the ability to detect the source of such a fault may provide significant advantages in operating a dense system. For example, where a large number of point to point systems are deployed, a particular transmitter's antenna may be blown out of alignment only a few degrees. Although, the present invention's use of monitored received signal performance will allow the transmitter power to be dynamically adjusted so that the associated receiver is not unduly affected by this slight shift in the transmit antenna, another receiver in the network may begin to experience interference. If it were not for the above described historical measurement of the customary transmission power level for the transmitter for which the antenna has been misadjusted, a technician may attempt to solve the problem at the affected receiver site, its corresponding transmitter site, or other transmitters in the area, without any guidance as to the particular transmitter actually sourcing the problem.

It should be appreciated that a technical advantage of the present invention is that a system and method which is adapted to adjust transmit power levels in order to maintain desired link performance levels is provided. Moreover, the system and method is adapted so as to allow for rapid adjustment of such link performance even where measurement of the performance level requires a lengthy determination.

A further technical advantage is realized in that the present invention may be utilized in providing a dense deployment of communication systems by maintaining a minimum antenna beam contour at each receiver/transmitter pair. Accordingly, the available spectrum may be utilized to provide additional bandwidth at each receiver/transmitter pair rather than in avoiding co-channel interference.

A still further technical advantage is realized in that the present invention adjusts communication parameters in order that dynamically changing circumstances are compensated for.

The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be

better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIGURE 1A shows the radiation pattern contours of a prior art point to point communication system;

FIGURES 1B and 1C show incidents of interference as between closely located transmitter/receiver pairs;

FIGURE 2 shows the radiation pattern contours of a point to point communication system adapted according to the present invention;

FIGURE 3 shows a block diagram of a preferred embodiment of a control system according to the present invention;

FIGURE 4 shows a flow diagram of the power requirement algorithm of the control system of FIGURE 3;

FIGURE 5 shows a flow diagram of the power change algorithm of the control system of FIGURE 3; and

FIGURE 6 shows a flow diagram of an alternative embodiment of the power change algorithm of the control system of FIGURE 3.

DESCRIPTION OF THE INVENTION

In a typical point to point communication system communication links are established between a transmitter and receiver pair in order to carry signals and information there between. For example, directing attention to FIGURE 1A wherein a prior art point to point communication link is shown generally as system 100, transmitter 101 and receiver 102 form a transmitter/receiver pair. Here transmitter 101 has main beam 111a directed toward receiver 102 in order to establish a wireless communication link suitable for providing signals and information there between. Transmitter 101 also includes area of influence 121a, which may consist of side lobes, back lobes, and the like, wherein signals radiated by transmitter 101 may be received outside of main beam 111a.

Accordingly, any receiver disposed within either main beam 111a or area of influence 121a may establish communication with transmitter 101. However, in a point to point system, it is typically desired that only a single receiver establish communication with a particular transmitter. Therefore, the portions of main beam 111a extending beyond receiver 102 (the main beam shadow) potentially introduce interference into the communication links of other transmitter/receiver pairs. Likewise, area of influence 121a potentially introduces interference into the communication links of other transmitter/receiver pairs.

The environment into which such communications links are typically deployed include dynamically changing circumstances which may affect the propagation of radiated signals. For example, the difference in signal attenuation between a transmitter and receiver from a clear to rainy day may be as much as 40dB per km. The effects of such temporary circumstances are illustrated as attenuated main beam 111b and attenuated area of influence 121b.

It shall be appreciated that, in order to provide a sufficient signal to be received by the receiver of a transmitter/receiver pair during periods of extreme signal attenuation, the transmitter of the transmitter/receiver pair must transmit at an increased power level, even during periods of reduced signal attenuation, where the system utilizes a constant transmitted signal power level. Therefore, other such transmitter/receiver pairs in such a prior art system must either be excluded from these areas or must utilize a portion of the spectrum sufficiently different to avoid co-channel interference.

Moreover, as the conditions affecting the link parameters may not be constant over large areas, i.e., the rain rate is never uniform over a large area of many miles, and thus is not completely predictable, the system is typically designed for worst case scenarios wherein a

condition has a maximum effect on the link throughout the link distance. Only then may confidence be instilled that the link may be maintained during all conditions. Therefore, the area in which other such transmitter/receiver pairs must be excluded may be unnecessarily enlarged in order to be confident that the effects of co-channel interference are remediated under all circumstances.

For example, consider two radio links 151 and 152, where two receivers, receivers 161 and 171, are closely located as shown in FIGURE 1B. For simplicity, it is assumed that the distance between one transmitter, transmitters 162 and 172, to both receivers is approximately the same. Accordingly, the signal level at the antenna input of the receivers, with respect to signals from both transmitters, is approximately the same level, i.e., link signal 151 and interference signal 154 at receiver 161 are approximately the same level and link signal 152 and interference signal 153 at receiver 171 are approximately the same level, although having a different incident angle. However, the received signal after acceptance by the antenna will be different due to the antenna pattern having a variable gain with incident angle. The design of link 151 has to make sure that the ratio of link signal 151 to interference signal 154 is sufficient to meet the performance requirement.

For 20 to 40 GHz radio transmission systems, the propagation loss is a time variant due to water vapor in the air, like rain. A rain margin of 20 to 50 dB is a necessity for a reasonable hop distance. For systems that have no power control, the transmitted power level is constant and includes these rain margins all the time. On a clear day, the propagation loss is low, so the received signal is high and so is the interference. However, since the rain fall density is not always uniform over a large area, the propagation loss between links 151 and 152 are also a time variant, especially during heavy rain.

FIGURE 1C shows a case where the propagation loss difference is at the extreme, e.g., one link has area of rain 180, while the other is not affected. Assuming the ratio of signal to interference at receiver 161 under normal conditions is XdB and the loss due to rain is YdB, where Y could be a large number like 20 dB. The signal to interference ratio for the case shown in FIGURE 1C is (X-Y) dB. This means the link budget design must include the interference and propagation loss between the intended path and the interfering path.

The present invention utilizes automatic link parameter adjustment, such as power control adjustment to maintain a constant link characteristic as received when the propagation loss is time variant. Directing attention to FIGURE 2, the contour of a communication system

200 having a transmitter/receiver pair operating according to the present invention is shown. Here transmitter 201 has main beam 211 directed toward receiver 202 in order to establish a wireless communication link suitable for providing signals and information there between. Transmitter 201 also includes area of influence 221a, which may consist of side lobes, back lobes, and the like, wherein signals radiated by transmitter 201 may be received outside of main beam 211.

Accordingly, any receiver disposed within either main beam 211 or area of influence 221a may establish communication with transmitter 101. However it should be appreciated that the area associated with both main beam 211 and area of influence 221 are significantly smaller than those shown in FIGURE 1A discussed above. Accordingly, additional transmitter/receiver pairs may be deployed much more closely to the transmitter/receiver pair of FIGURE 2.

In order to avoid signal degradation or communication link failure during the aforementioned occurrences of dynamically changing conditions, the system of FIGURE 2 operates to measure link characteristics at receiver 202 and adjust transmission at transmitter 201 to provide a substantially constant communication parameters as measured at the receiver. This is illustrated as main beam 211 remaining substantially a constant size, i.e., no attenuated main beam is illustrated as in the system of FIGURE 1A.

However, as communication parameters must necessarily be adjusted to compensate for the changing conditions, i.e., the transmit power level of transmitter 201 is increased to remediate attenuation due to precipitation, the area of influence 221a may not remain constant as illustrated by slightly enlarged area of influence 221b. For example, the transmitted power may compensate for the propagation loss in the main beam and over compensate in the sidelobe areas. As it is of primary importance to maintain the communication link between transmitter 201 and receiver 202 and, if possible, maintain a consistent link performance characteristics, the fluctuation in this area of influence is tolerable according to the present invention provided it does not vary enough to present undesired interference with co-existing transmitter/receiver pairs or otherwise introduce undesired results.

When systems with power control are deployed according to the present invention, the received signal level is maintained at an approximate constant. Accordingly, the difference in propagation between the links is immaterial, because the signal and interference level will be

maintained as a constant. Therefore, it is desirable to have a power control range that is greater than or equal to the rain margin.

From the above it may be seen that, in terms of system operation point of view, major differences in the prior art system and that of the present invention exist in that the constant transmitted power system of the prior art is interference limited during periods of low propagation loss (on a clear day) and thermal limited during periods of high propagation loss (on a rainy day), while the constant received signal power system of the present invention is thermal limited all the time. Moreover, since the rain rate is never uniform over a large area of many miles, the transition from the interference to thermal limited condition of the prior art system will not be uniform. Accordingly, the overall network performance is extremely complex to analyze, and therefore difficult to deploy additional non-interfering transmitter/receiver pairs. Additionally, it is very likely that not every link with a constant transmitted power line will meet the performance requirement with some rain pattern.

In contrast, the constant received power system of the present invention has a small area of variation. Accordingly, the performance management of a radio network is feasible.

Directing attention to FIGURE 3, a block diagram of a transmitter/receiver pair adapted according to the present invention is shown. According to the present invention, a control system is included to maintain link parameters at a constant level under all propagation loss conditions over a radio link. Preferably, the control system utilizes a closed loop power control system wherein the received signal error level is detected and used to adjust the transmitted power.

As shown in FIGURE 3, the preferred embodiment of the present invention includes two parts functioning to provide a closed loop control system. Preferably, a portion of the control system is deployed in or with receiver 202, shown in FIGURE 3 as power requirement algorithm 320, and another portion of the control system is deployed in or with transmitter 201, shown in FIGURE 3 as power change algorithm 310, in communication through link 300.

An advantage in providing the control system at least in part in the receiver is that it is at the receiver that the signal characteristics as actually experienced over the link are most easily measured. An advantage in providing the control system at least in part in the transmitter is that not only may the controller operate to adjust the transmitter as requested, but if any fault develops in the system, the control system may recognize the fault condition and determine whether leave the transmitter adjusted as it is, or adjust the transmitter in

response to the fault condition. For example, the control system may command the transmitter to reduce transmission power during certain detected faults, irrespective of a request for increased power, as in particular instances if transmitter transmits more power it is not going to improve the signal as received by the receiver.

In the preferred embodiment, power requirement algorithm 320, operating on a processor based system such as with CPU 302 of receiver 202, is coupled to receiver circuitry, such as demodulator 304, to accept signals therefrom and to determine whether attributes of the received signal are above or below a predetermined acceptable level. A request of power change output will be sent, such as through a reverse channel of link 300, to transmitter 201 on other side of the radio link.

It shall be appreciated that in a typical point to point system each site includes both a transmitter and a receiver, i.e., a reverse link substantially the same as the forward link illustrated in FIGURE 2 exists for each transmitter/receiver pair. Generally this reverse link operates at a different frequency than that of the forward link, i.e., frequency division of forward channels and reverse channels. Of course, the reverse link may be established through time division duplexing (TOD), CDMA, or other such multiple access schemes, if desired. The reverse link is generally utilized for subscriber payload, i.e., the subscriber utilizes a bidirectional information link. Often, however, a control channel is included in this reverse channel link (control channels may also be included in the forward link). Accordingly, the present invention utilizes this control channel in providing a link between the portion of the control system disposed in the receiver and that disposed in the transmitter.

The control channel may be a bit overhead on each packet of data sent and, therefore, somewhat limited in bandwidth. Accordingly, the present invention is preferably operable to optimize the communication of control system information in the control channel.

However, it should be appreciated that the use of a control channel in an existing bidirectional link between the transmitter/receiver pair is not necessary for the operation of the present invention. For example, a reverse channel link may be established solely for the control system information communication of the present invention. For example, where only a mono-directional wireless link is deployed, the control system of the present invention may utilize other means for communication link parameter adjustment information, such as a public switched telephone network(PSTN), a wide area network (WAN), the Internet, a cable system, or the like. Moreover, as the reverse channel necessary for operation of the preferred

embodiment is optimized, the reverse link utilized may provide a substantially narrower bandwidth than that of the forward link subscriber communication, thus minimizing its cost and complexity. Additionally, the us of such a link external to the point to point system may accommodate a forward link control channel and thus free up additional subscriber pay load.

In the preferred embodiment, power change algorithm 310, operating on a processor based system such as CPU 301 of transmitter 201, is coupled to transmitter circuitry, such as transmit radio frequency (Tx RF) modules 303, to accept the request from power requirement algorithm 320 and determine whether transmitter 201 should be adjusted as requested or not. If it is determined that the transmitter 201 should be adjusted, a command signal is provided by power change algorithm 310 to adjustment circuitry of transmitter 201, such as an electronic controlled attenuator located in Tx RF modules 303.

It shall be appreciated that although the preferred embodiment described above utilizes CPUs associated with transmitter 201 and receiver 202 for operation of power change algorithm 310 and power requirement algorithm 320 respectively, this is not a limitation of the present invention. For example, an alternative embodiment of the present invention may utilize general purpose processor based systems, such as a personal computer system based on the INTEL 80X86 family of central processors, having memory associated therewith in order to store and execute the above algorithms and being adapted to interface with transmitter 201 or receiver 202.

As described above, preferably the receive demodulators are the source of information with respect to the receive side of link 300. Utilizing demodulators 304, power requirement algorithm 320 is able to acquire information with respect to link performance. For example, in the preferred embodiment, from information provided by demodulators 304, power requirement algorithm 320 is provided information with respect to the bit error rate (BER) of the signal as well as receive signal strength indicators. Based on this information, power requirement algorithm 320 can determine in real time whether the power should be adjusted from the current levels and, if so, whether this adjustment should be up or down.

Directing attention to FIGURE 4, a flow diagram of the operation of power requirement algorithm 320 according to a preferred embodiment of the present invention is shown. In the preferred embodiment, link performance as experienced by the receiver is measured in the adjusting of link parameters to compensate for changing link conditions. Accordingly, power change algorithm 320 measures the BER of the communication link. Of

course, other measurements of link performance may be made according to the present invention, if desired. For example, an alternative embodiment of the present invention may measure received signal characteristics such as received signal level, received signal level to noise level, or the like.

In providing a high speed data communication system, it is desired that the data communicated be reliable and that retransmission of data be avoided in order to avoid wasting bandwidth with repeated transmission of information. Accordingly, the link error rates are preferably set quite low. For example, a BER established for a particular link may be on an order of magnitude of 10^{-12}, i.e., in every 10^{12} received bits, one error will be experienced. Accordingly, where the link is transmitting at 100 Mbits per second, it would take 2.78 hours to detect one error.

Preferably, the control system of the present invention operates to substantially match adjustment of the communication system to the rate of environment change, or other dynamic conditions affecting link performance, in order to maintain the desired link performance level. However, matching the rate of environment change in many cases would require continuous and instantaneous measurement of link performance and adjustment of link parameters. Alternatively, such continuous and instantaneous measurements and adjustment may be dispensed with in favor of incremental measurement and/or adjustment, i.e., providing margins in which operation is allowed.

There is a trade off as to the adjustment step size versus how frequently such adjustments are made. If the system were to make adjustments slowly, then larger adjustment steps are required to match the environmental changes. In order to maintain at least a minimum desired link quality between such large adjustment steps, a larger margin in the link quality as experienced by the receiver must be tolerated.

For example, where the measurement of link performance is accomplished through reference to a receive signal strength, a particular power level may be selected, i.e., X dB. If adjustments are to be made in increments of 1 dB, even when the receive signal is strong, the system would have to operate at X+1 dB in order to allow for link degradation to the preselected minimum of X dB prior to the minimum incremental adjustment of 1 dB. This, however, translates into increases in the areas of exclusion around this transmitter/receiver pair as the transmitter is transmitting at all time a power level sufficient to compensate for the large incremental adjustment established.

Moreover, if the adjustment steps are too large, the receiver might not be able to work properly. For example, suddenly making large changes in the transmitted power level may cause problems in the receiver AGC, locking loops, etcetera. Accordingly, it is desirable to make determinations as to the need to adjust transmission parameters sufficiently often enough to allow a desired and tolerable level of incremental adjustment to be employed.

However, it may not always be possible to make such rapid determinations. For example, the above described preferred embodiment utilizing BER determinations may require substantial lengths of time to determine. It should be appreciated that environmental conditions may be change substantially in such lengths of time.

Accordingly, the preferred embodiment of the present invention utilizes multiple processes to determine link quality, preferably a slow more accurate process and a fast more coarse process. Ultimately it is desired that the information of the slow process will be the link performance reference point as this is the quality to actually be delivered, however, through correlation of the coarse process to the determinations of the fine process, instantaneous or nearly instantaneous determinations of link performance may be made.

The accurate measure of link performance, or fine BER measurement in the preferred embodiment, requires a long time to actually measure. Specifically, determination of fine BER is generally accomplished by counting the number of bit errors in an interval. The accuracy of the measurement is based on the number errors being counted during the measurement interval. Since it takes a long time to get some accuracy, a good compromise solution is to record the interval between two consecutive errors. The computation of fine BER may utilize a determination of the average error interval over last x errors, e.g. the last 10 errors. The number of bits in the average error interval is the bit rate times the average error interval. The fine BER is 1 over the number of bits in the average error interval. This measurement scheme allows the fine BER to be updated once every detected error.

However, there are less accurate indications of link performance which may be measured more quickly and, if utilized properly, can be used to provide a very good indication of the actual link performance. In the preferred embodiment of FIGURE 4, two link parameters are measured very quickly, i.e., substantially instantaneously and continuously. Specifically, the receive signal strength indicator (RSSI) and coarse BER are measured for use in making a coarse link performance determination.

It is anticipated that the information communication of the transmitter/receiver pair of the present invention will utilize some form of error correction coding. Accordingly, the majority of transmission errors may be detected and corrected prior to the information being presented to the subscriber. The coarse BER of the present invention taps the error rate before such error correcting codes are utilized to correct transmission errors. Accordingly, errors may be detected much faster than if referencing the error rate as experienced by the subscriber.

However, there is not a one to one correlation between the coarse BER and the BER as experienced by the subscriber. Therefore, the preferred embodiment of the present invention utilizes a second link parameter in its coarse determination of link performance in order to more accurately correlate this information to the fine BER.

Moreover, it shall be appreciated that if a single link parameter measurement is relied upon alone for the fast determination of link parameter adjustment, hysterisis in the adjustment may be a problem. For example, due to noise and other phenomena affecting the communication link, if only the coarse BER were utilized in making the adjustment determination there may be a constant adjusting of the communication parameter as the coarse BER will likely fluctuate quite a bit, i.e., the coarse BER may be different for every half second in which adjustments are made. However, it is typically not desired to continuously adjust the transmitter, i.e., one up, one down, one up, one down, in response to such temporary variations which do not significantly impact link performance.

Accordingly, the preferred embodiment utilizes two measurements, both RSSI and coarse BER. When both are better than the reference (exceed a threshold, whether a ceiling or floor threshold), it is likely that the system is really transmitting too much power, and downward adjustment is advisable. However, if both are poorer than the threshold (do not exceed a threshold, whether a ceiling or floor threshold), it is likely that the system is really transmitting too little power, and upward adjustment is advisable. Where one of the parameters is better (exceeds a threshold, whether a ceiling or floor threshold) and the other parameter is poorer (does not exceed a threshold, whether a ceiling or floor threshold), this may be indicative of a slight environmental or other phenomena affecting the communication link, not worthy of adjustment in the link parameters.

Using the same method as described above with respect to the fine BER, the average coarse BER and the average RSSI are computed over each error interval. Accordingly, the final average coarse BER and RSSI computation will be based on the same interval as used for

the fine BER computation, although these averages may be updated much more often than that of the fine BER.

Preferably the control system takes a plurality of samples of RSSI and coarse BER between two consecutive power change requests. In the preferred embodiment, the number of samples taken is based on the variation from one sample to another. Accordingly, where the system is fairly stable, processing power may be conserved by taking fewer samples and performing fewer calculations etcetera. However, where the system is experiencing more rapid variations, the control system reacts to make more rapid measurements in order to compensate for these variations more quickly and more accurately.

As shown in FIGURE 4, the preferred embodiment computes the BER as experienced by the subscriber (box 401), which might take a couple of hours, and simultaneously measures the RSSI and course BER (box 403) to establish a reference. By recording the measured RSSI and coarse BER, an average of these measurements may be correlated to the fine BER ultimately measured for use in making more accurate fast determinations as to link performance (box 402), i.e., the slow measurement of link performance is translated into a fast measurement of link performance reference point.

The purpose of the correlation of the BER to RSSI and coarse BER in the preferred embodiment is to determine what the measured RSSI and coarse BER thresholds should be to achieve a desired fine BER, i.e., a BER that was defined by the system performance requirements. Based on the fine BER, average RSSI and coarse BER measurements, the correlator will set the RSSI and coarse BER thresholds either above or below the average RSSI and coarse BER depending on whether the fine BER as actually measured is worse or better than expected.

Once this slow measurement of link performance is transferred to a fast measurement reference point, thresholds may be established for substantially instantaneous or real time adjustment of the link parameters. This information may be utilized in determining if the currently measured parameters, i.e., coarse BER and RSSI, indicate adjustment of the link parameters is desired.

Specifically, if the coarse BER is lower than the threshold reference associated with the desired fine BER (box 404) and the RSSI is greater than the threshold reference associated with the desired fine BER (box 405) then a determination that the power level should be decreased may be made (box 407). Contrariwise, if the coarse BER is greater than the

threshold reference associated with the desired fine BER (box 404) and the RSSI is greater than the threshold reference associated with the desired fine BER (box 406) then a determination that the power level should be increased may be made (box 407). However, if the coarse BER is lower than the threshold reference associated with the desired fine BER (box 404) and the RSSI is lower than the threshold reference associated with the desired fine BER (box 405) or if the coarse BER is greater than the threshold reference associated with the desired fine BER (box 404) and the RSSI is greater than the threshold reference associated with the desired fine BER (box 406) then a determination that the power level should remain the same may be made (box 407).

Accordingly, the decision algorithm decides what should be the next request with respect to the power level; increase, decrease, or no change. The power level change is based on the positive indications, i.e., both RSSI and coarse BER are better or poorer than the threshold. The less conclusive indications for changes, where only one of two parameters is better than the threshold, preferably result in no communication link adjustment.

The particular determination made according to the power requirement algorithm is preferably communicated to the portion of the control system actually operating to adjust the transmitter (box 408). However, it shall be appreciated that where no adjustment is desired, transmission of this determination may be omitted in order to avoid unnecessary utilization of a reverse link. Alternatively, the transmission of this "no change" information may be desired, such as where the determination is periodically and systematically communicated for use at the transmitter, such as to determine the continued operation of the portion of the control system deployed at the receiver.

Having described the preferred embodiment of power requirement algorithm 320 of the present invention, reference is now made to FIGURE 5 wherein a flow diagram of the preferred embodiment of power change algorithm 310 is shown. Preferably each link has associated therewith a maximum and minimum power level setting to protect each radio and/or other communication links during the occurrence of an abnormal condition. In the preferred embodiment this information is provided in a database, or other knowledge base, or reference table associated with, or accessible to, power change algorithm 310 as illustrated by box 501.

In the preferred embodiment, the maximum power level is set as a function of the link distance and link performance requirement. The minimum power level is also preferably

established as a function of the link distance and link performance and may be utilized primarily to insure that the system is not totally turned down in order to minimize the start up process.

For example, considering two radio links; one radio link may have a longer link distance than the other. The longer distance link would typically have associated therewith a higher maximum and minimum power level than the shorter distance link. Another example is that two radio links, although having the same link distance, may have a different link availability performance requirement. Accordingly, the link having a higher link availability requirement would typically have a higher maximum power level than the link having the lower link availability requirement. Here, however, the minimum level would likely be the same for each link.

The nominal power level shown in the embodiment of FIGURE 5 is preferably the power level that is transmitted most of the time. This nominal level may be computed from the link distance and/or may be computed from historical information associated with the link. In the preferred embodiment of the present invention the nominal power level is used as a reference level, such as a reference value to determine if the system is operating too long at a excessive power level, thus indicative of a system fault or some other unusual condition. Moreover, the nominal power level may be used to set the minimum transmitted power, e.g. the minimum power level may be set as X dB below the nominal power level.

The setting of link parameter ranges preferably accommodates the occurrence of special conditions. For example, the minimum power level may be set in case some extraordinary environmental condition or other anomaly occurs which temporarily makes the path a lot less lossy. If such a phenomena happens, it may not be desirable to adjust the power level below a certain point, although communications may be maintained during this phenomena, because when the phenomena disappears there may be no way to adjust the communication parameters quickly enough to avoid undesired loss of the link or other communication problems.

Similarly, the maximum power level may be set to avoid upwardly adjusting the power level in response to a phenomena which is such that no amount of power level adjustment would maintain the desired link performance. For example, it shall be appreciated that by setting the maximum level to, or slightly greater than, the least possible setting for maximum attenuation, such as may be accomplished by the below described calibration technique and/or through reference to historical operating conditions of the link, the system will allow

compensation for such conditions while not allowing uncontrolled power increases when equipment fails that causes the service outage.

It should be appreciated that the use of the aforementioned values defining a power range allows the present invention to be adjusted for various conditions as well as to adapt according to historical information or other sources of a knowledge base. For example, in some cases it may be desired to provide link reliability of 99.999% ("five nines"), or that it is acceptable to loose data transmission for a total of 5 minutes per year, such as due to rain attenuation. This level of link reliability would require more power to compensate for times of heavy attenuation. Accordingly, the maximum power associated with the power range of power change algorithm 310 would be set higher. However, in some cases link reliability of 99.99% ("four nines"), or loss of data transmission for a total of 15 minutes per year, is acceptable. Then the maximum power level associated with the power range may be set to a lower level.

Moreover, it should be appreciated that the use of these adjustable parameters in the algorithm allows a single algorithm to operate the system within the designated parameters, which may be changed from time to time or from deployment to deployment, without the need for separate algorithms or functions for particular operating states or conditions. Instead, a single algorithm may simply determine if the requested adjustment is within the allowed parameters and make this change without actually determining under what conditions the system is operating. Accordingly, the present invention provides a simple but effective way in which a standard system may be developed and deployed and yet be adjusted for each link's operating environment, both initially upon deployment and later in response to historical operating information.

Power change algorithm 310 of the preferred embodiment operates to accept the power level change requests generated by power requirement algorithm 320 as illustrated in FIGURE 5. Thereafter, the algorithm, through reference to the aforementioned power range information (box 501), determines if the requested power change would be within this range (box 502). If the requested change is within the power range, the change is executed as requested. However, if the change is not within the power range, the request is not implemented. For example, if a request for increased power is received, but the system is already operating at the maximum power level the requested power change would not be within the allowed range and, therefore, the request would not be honored.

If the decision is to change the transmitted power, then a message or control signal will be sent from power change algorithm 310 to Tx RF modules 303 to change the attenuator value. In a preferred embodiment, the adjustment in power level is in consistent increments. For example, if power change algorithm 310 instructs the attenuator to increase the transmitted power level, a single unit of power level increase is incremented. Likewise, if power change algorithm 310 instructs the attenuator to decrease the transmitted power level, a single unit of power level increase is decremented.

However, in an alternative embodiment, the link parameter adjustments may be nonlinear. For example, when increasing the power the system may increment in bigger steps but when decreasing the power the system may decrement in smaller steps. Likewise, the system may determine the frequency of parameter adjustment requests, i.e., successive requests to increase power, and make fewer larger adjustments rather than more smaller adjustments as these requests are repeated. For example, if the thresholds are crossed one time, the system adjusts the link parameter by one step. However, if the same thresholds are crossed a second time within a predetermined period of time, the system may adjust the link parameter by two steps. Alternatively, two sets of thresholds may be provided wherein if the first thresholds are crossed, the system adjusts the link parameter by one step, but if he second thresholds are crossed, the system adjusts the link parameter by two steps. These embodiments may be preferred where sudden attenuation is experienced such as through "cloud burst" type rain fall where small incremental steps in power increase may be insufficient to compensate for the very substantial and almost instantaneous attenuation.

It shall be appreciated that the size of these incremental adjustments as well as the conditions under which alternative incremental adjustments may be utilized may be provided in a database, or other knowledge base, or information table such as that utilized by the power range described above. Accordingly, as with the power range, the incremental adjustments may be tailored for the particular environment into which the system is deployed. This information may actually be stored within the same database, illustrated as box 501, as the power range. Alternatively, a separate database could be provided to store this information (not shown).

At initial power up, it is preferred that the system not wait for the fine BER measurement before starting operation according to the present invention. Accordingly, a set of default values, such as might be loaded from the factory, are utilized to get the system

started. These defaults may be substantially arbitrary with respect to the particular link established or may be based on parameters known at the time of installation, such as link distance, for example.

When the system is operational, but either the fine BER cannot be measured, e.g. no error detected or just after power-up, a system calibration is preferably performed. This system calibration is utilized to establish the thresholds for determining link parameter adjustment and also preferably includes adjustment of the aforementioned default values of the power range information.

For example, it may take a long time to measure a particular desired error rate, assuming errors on the order of magnitude of 10^{-12}. So after a lengthy period of measuring errors it might be concluded that there is substantially no error. Initially, it might appear that this conclusion of substantially no error is desired. However, if the system does not accurately know what the error rate is, it is possible that the system is transmitting with too much power thus, although providing a substantially error free link, interferes with other communications.

According to a preferred embodiment, calibration is performed by reducing the value of the three parameters, fine BER, coarse BER, and RSSI, which will cause the power requirement algorithm to force the transmitted power to go down. The reducing of these values is repeated until some measurable errors are detected. Once errors are detected, these values, or ones of these values, may again be adjusted, or increased, to achieve the desired link performance level.

In most cases, it is preferred that the design of power control system is set to operate slightly above the required performance to allow for some degradation between adjustments. Accordingly, a margin in the actual measured communication parameters and the required communication parameters, those suitable to result in the required link performance, is required. Therefore, the correlator of the preferred embodiment inserts system margins, where desired. For example, although the correlator determines that a particular RSSI, in combination with a particular coarse BER, is suitable for providing the desired link performance, the correlator provides a system margin in this determined value of RSSI. Accordingly, the correlator introduces or increases system margin by rasing the thresholds.

One of tasks during installation and commissioning of the point to point transmitter/receiver pair is to align both antennas, i.e., in order that each antenna will be pointing at the other. However, as large distances may be spanned by such a system, the

physical misadjustment of an antenna only a few degrees may result in one or both antennas aligned on a sidelobe, i.e., the antennas are pointing at each other on sidelobes rather than the main beam, where there is enough transmitted power to let this happen.

The preferred embodiment of the present invention avoids establishing communications through these undesired links by reducing the maximum power level of the power range to just above the nominal level (or level expected for communications over this particular length of link through the main antenna beam). Under this condition, the system can only work when the antenna is pointing at each in main beam. Moreover, this technique results in reducing the interference to installed-based radios during the alignment process by pointing the radio at wrong directions.

A preferred embodiment of the present invention is adapted to recognize and react to system faults, especially those which may result in adjusting link parameters such that interference may be introduced into other links. Directing attention to FIGURE 6, a flow diagram of a preferred embodiment of power change algorithm 310 is shown having a decision box therein in for determining system faults (box 601).

Accordingly, in this embodiment requests for power level adjustments may not only be subject to a determination that the requested change is within the limits of the system as in FIGURE 5, but will also be subject to a determination that the system is not in fault. If the system is determined to be in fault the system may be shut down and an operator notified. Alternatively, if the system is determined to be in fault, the system may continue to transmit at some predetermined level, such as the aforementioned nominal power level or the maximum power level, in order to potentially provide communication, although likely not at the desired link performance level.

System faults may be determined to exist through such means as measuring a duration at which the system is operating at a power level substantially higher than the nominal power level. For example, if experience has revealed that periods of substantial attenuation occur only briefly and the system has been operating at an increased power level for a length of time in excess of the historically experienced times, then a conclusion may be made that the system is in fault.

Likewise, the system may determine a fault condition from the number, type, and/or frequency of power change requests. For example, the system may continue to receive only requests to increase power levels over a long period of time. This might be indicative of

antenna alignment drift rather than environmental conditions to be compensated for. Accordingly, the system may operate to determine that such increases are no longer prudent and notify an operator of a potential fault condition.

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS

1. A point to point communication system comprising:

a transmitter having a main antenna beam contour associated therewith;

a receiver in communication with said transmitter through a link established through said main antenna beam; and

a controller adapted to measure link attributes as experienced by said receiver and to control said transmitter to maintain said main antenna beam contour substantially as a constant.

2. The system of claim 1, wherein said attributes measured by said controller include a performance characteristic of said link and at least one additional attribute.

3. The system of claim 2, wherein said controller correlates said performance characteristic to said at least one additional attribute, wherein said performance characteristic requires a longer time to measure than said additional attribute and a currently measured said additional attribute through use of said correlation is relied upon to determine a current said performance characteristic.

4. The system of claim 3, wherein said performance characteristic is a fine bit error rate and said at least one additional attribute includes a coarse bit error rate.

5. The system of claim 1, wherein said controller includes link attribute range information to prevent said controller from controlling said transmitter to operate outside said attribute range.

6. The system of claim 5, wherein said attribute range includes a maximum power and a minimum power.

7. The system of claim 6, wherein said maximum power is established slightly above a nominal power level during an installation phase of said link.

8. The system of claim 7, wherein said maximum power is established slightly above a power level determined to be sufficient for a worst case attenuation condition during an operational phase of said link.

9. The system of claim 1, wherein said controller is at least in part disposed co-located with said transmitter.

10. The system of claim 9, wherein said controller is at least in part disposed co-located with said receiver.

11. A system for providing a substantially consistent performance characteristic in a link between a transmitter and receiver pair of a communication network, said system comprising:

a monitor disposed at least partially at said receiver to monitor said performance characteristic and at least one attribute of said link in addition to said performance characteristic, wherein said monitor is adapted to correlate the at least one monitored additional attribute with the monitored said performance characteristic to thereby provide correlated information, and wherein said monitor provides a link manipulation control signal as a function of currently monitored said at least one additional attribute and said correlated information; and

a manipulator disposed at least partially at said transmitter to manipulate said link as a function of said link manipulation control signal and a determination of manipulation in response to said link manipulation control signal being within preestablished operating parameters.

12. The system of claim 11, wherein said at least one additional attribute includes a receive signal strength and a coarse bit error rate.

13. The system of claim 11, wherein said performance characteristic is a fine bit error rate.

14. The system of claim 11, wherein said at least one additional attribute is at least two additional attributes.

15. The system of claim 14, wherein said correlated information includes a first threshold value associated with a first attribute of said at least two additional attributes and a second threshold value associated with a second attribute of said at least two additional attributes.

16. The system of claim 15, wherein said control signal is a first value when both said first attribute and said second attribute do not exceed their respective threshold, said control signal is a second value when both said first attribute and said second attribute exceed their respective threshold, and said control signal is a third value when either of said first attribute and said second attribute does not exceed their respective threshold and the other one of said first attribute and said second attribute does exceed their respective threshold.

17. The system of claim 16, wherein said first value is associated with a power increase at said transmitter, said second value is associated with a power decrease at said transmitter, and said third value is associated with maintaining power at said transmitter.

18. The system of claim 11, wherein said preestablished operating parameters include a first power range.

19. The system of claim 18, wherein said first power range includes a maximum, a minimum, and a nominal power value.

20. The system of claim 19, wherein said manipulation of said link by said manipulator is also as a function of a determination of the existence of a fault condition.

21. The system of claim 20, wherein said determination of the existence of a fault condition is at least in part through reference to said nominal power value.

22. The system of claim 18, wherein said preestablished operating parameters include a second power range, wherein said first power range is associated with a first operating condition and said second power range is associated with a second operating condition.

23. The system of claim 22, wherein said first operating condition is an installation operating condition and said second operating condition is a deployed operating condition.

24. The system of claim 18, wherein values associated with said first power range are updated through reference to historical operating information associated with said link.

25. A method for maintaining a desired received signal quality, said method comprising the steps of:

measuring a first attribute of said received signal;

measuring a second attribute of said received signal;

measuring a third attribute of said received signal;

correlating measurements of said third attribute to measurements of said first and second attributes to thereby provide attribute correlation information;

establishing a first threshold value for said first attribute, wherein said first threshold value is associated with an acceptable state of said third attribute determined at least in part from reference to said correlation information;

establishing a second threshold value for said second attribute, wherein said second threshold value is associated with an acceptable state of said third attribute determined at least in part from said correlation information; and

generating a received signal control signal as a function of a comparison of a then measured first attribute to said first threshold and as a function of a comparison of a then measured second attribute to said second threshold.

26. The method of claim 25, wherein said third attribute is a fine bit error rate.

27. The method of claim 25, wherein said first attribute is a coarse bit error rate.

28. The method of claim 25, wherein said second attribute is a receive signal strength.

29. A method for controlling the transmission of a signal to maintain a desired received signal quality, said method comprising the steps of:

receiving information with respect to a comparison of a measured first attribute to a first threshold and a comparison of a measured second attribute to a second threshold, wherein said first and second thresholds are established at least in part through reference to a third attribute; and

determining if a signal transmission characteristic should be adjusted through reference to said received information, wherein said determining step includes reference to a preselected range of allowed signal transmission characteristics.

30. The method of claim 29, wherein said third attribute is a fine bit error rate.

31. The method of claim 29, wherein said first attribute is a coarse bit error rate and said second attribute is a receive signal strength.

32. The method of claim 29, further comprising the step of:
adjusting said preselected range from a first range to a second range.

33. The method of claim 32, wherein said second range is at least in part based on historical information.

34. The method of claim 32, wherein said first range is established as an initially acceptable range for deployment of a transmitter and receiver pair associated with said transmitted signal.

35. A method for reducing co-channel interference associated with a transmitter and receiver pair of a communication network, wherein said transmitter and receiver pair communicate through a wireless link, said method comprising the steps of:

measuring a first attribute of said link;

measuring a second attribute of said link;

measuring a third attribute of said link;

correlating measurements of said first attribute to measurements of said second and third attributes to thereby provide attribute correlation information;

establishing a second threshold value for said second attribute associated with an acceptable state of said first attribute from said correlation information;

establishing a third threshold value for said third attribute associated with an acceptable state of said first attribute from said correlation information;

generating a link control signal as a function of a comparison of a then measured second attribute to said second threshold and as a function of a comparison of a then measured third attribute to said third threshold;

determining if a link characteristic consistent with operation according to said link control signal is within a selected range; and

adjusting an attribute of said link if said link characteristic is within said selected range.

36. The method of claim 35, wherein said first attribute is a link performance characteristic.

37. The method of claim 36, wherein said performance characteristic is a fine bit error rate.

38. The method of claim 37, wherein said second attribute is a coarse bit error rate and said third attribute is a receive signal strength.

39. The method of claim 35, further comprising the step of:

adjusting said selected range from a first range to a second range.

40. The method of claim 39, wherein said second range is at least in part based on historical information of operation of said link.

41. The method of claim 39, wherein said first range is established as an initially acceptable range for deployment of said transmitter and receiver pair.

42. The method of claim 35, further comprising the step of:

comparing a nominal attribute of said link to said attribute of said link to be adjusted in said adjusting step to determine the existence of a fault condition.

43. A method for reducing co-channel interference associated with a transmitter and receiver pair of a communication network, said method comprising the steps of:

measuring a fine bit error rate at said receiver;

measuring a coarse bit error rate at said receiver;

measuring a receive signal strength at said receiver;

correlating measurements of said coarse bit error rate and said receive signal strength to said fine bit error rate to thereby provide correlation information;

establishing a threshold value for said coarse bit error rate associated with a desired fine bit error rate from said correlation information;

establishing a threshold value for said receive signal strength associated with a desired bit error rate from said correlation information;

generating a link control signal as a function of a comparison of a measured coarse bit error rate to said coarse bit error rate threshold and as a function of a comparison of a measured receive signal strength to said receive signal strength threshold;

determining if a transmission power of said transmitter consistent with operation according to said link control signal is within a selected range; and

adjusting said transmission power of said transmitter if said link characteristic is within said selected range.

44. The method of claim 43, further comprising the step of:

determining if a fault condition exists through reference to a nominal power level and said link control signal.

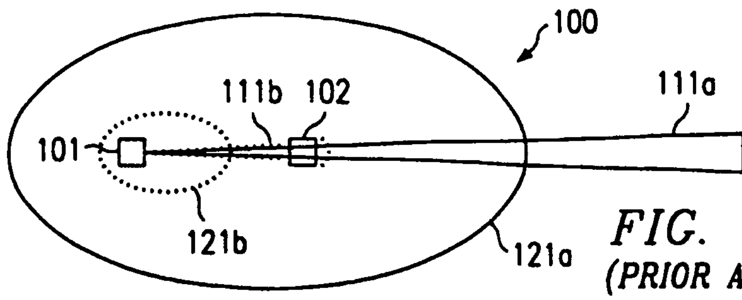

FIG. 1A
(PRIOR ART)

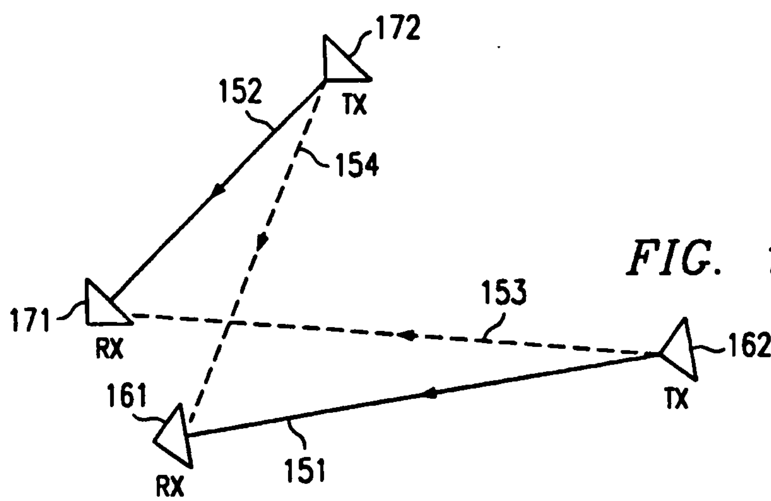

FIG. 1B

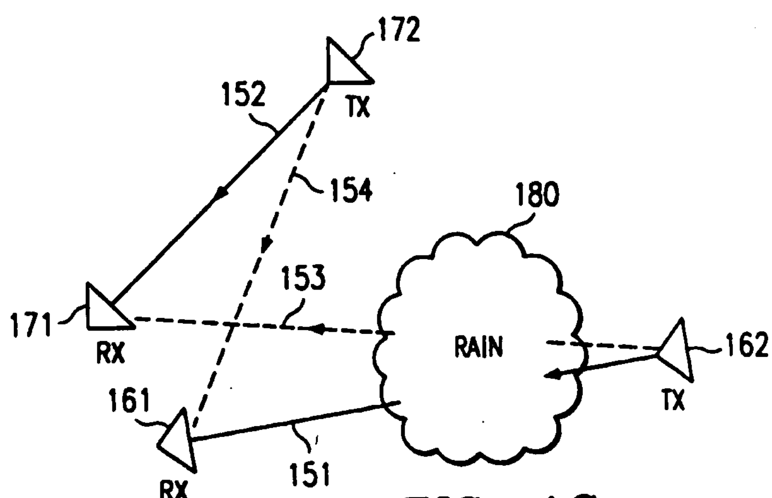

FIG. 1C

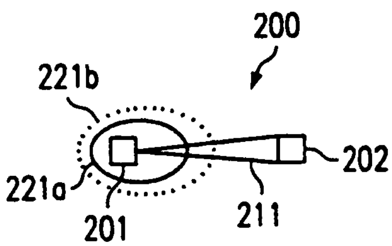

FIG. 2

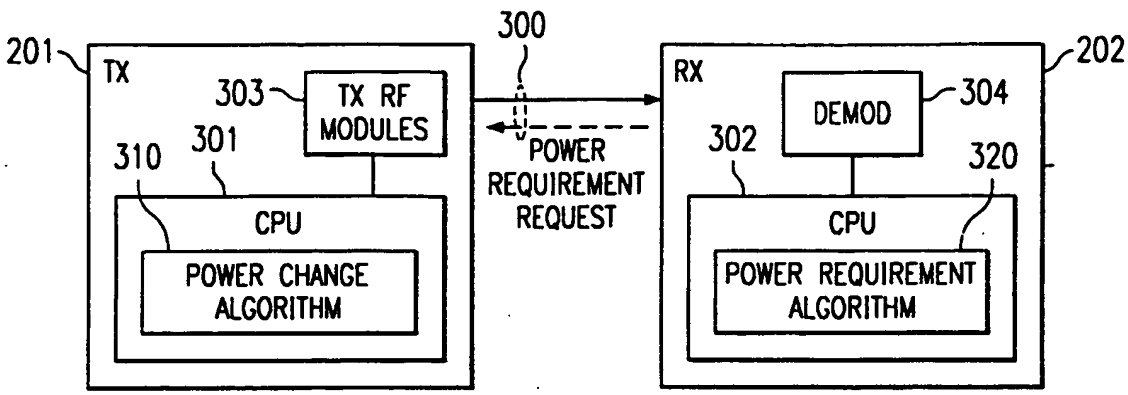
300
201
TX
303
TX RF MODULES
310
301
CPU
POWER CHANGE ALGORITHM
POWER REQUIREMENT REQUEST
202
RX
DEMOD
304
302
320
CPU
POWER REQUIREMENT ALGORITHM

FIG. 3

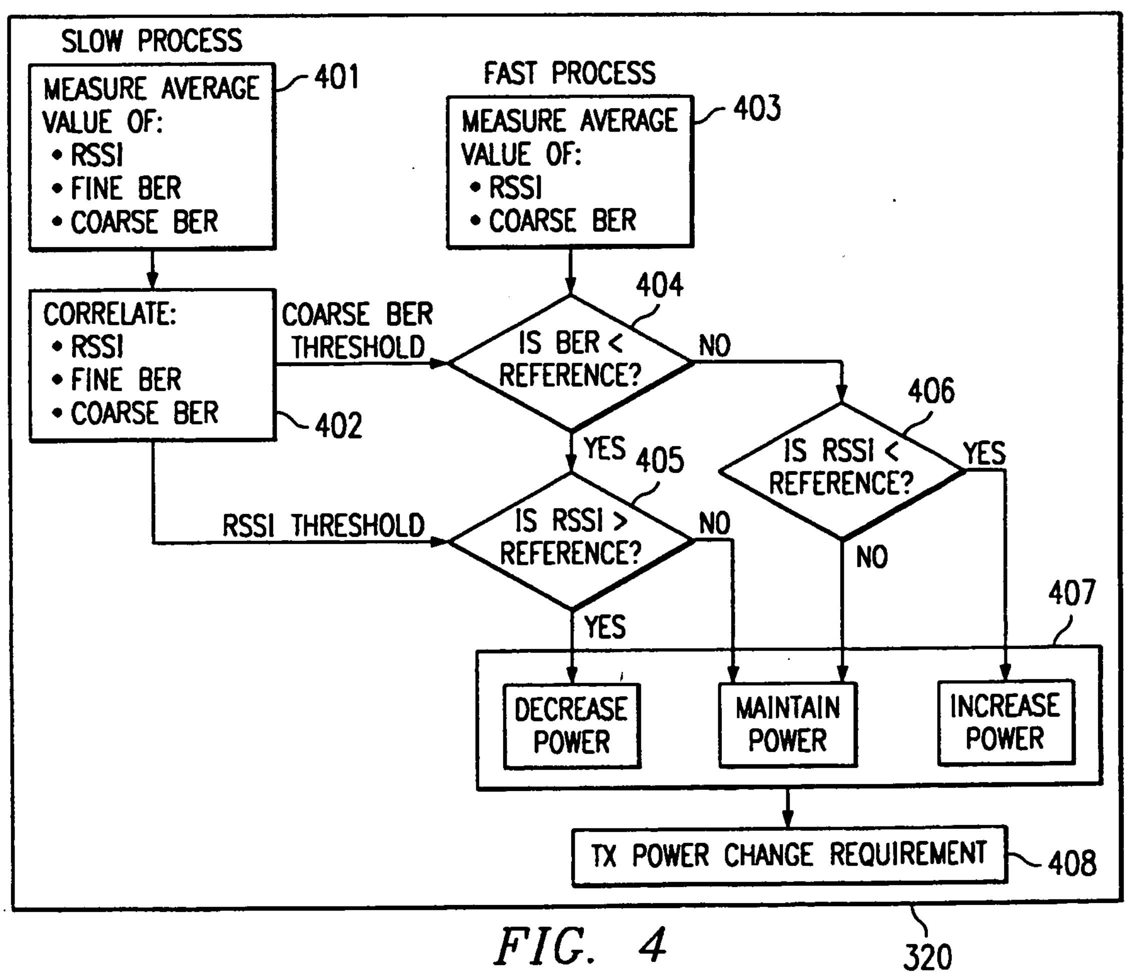
SLOW PROCESS
MEASURE AVERAGE VALUE OF:
• RSSI
• FINE BER
• COARSE BER
401
FAST PROCESS
MEASURE AVERAGE VALUE OF:
• RSSI
• COARSE BER
403
CORRELATE:
• RSSI
• FINE BER
• COARSE BER
402
COARSE BER THRESHOLD
404
IS BER < REFERENCE?
NO
YES
406
IS RSSI < REFERENCE?
YES
NO
RSSI THRESHOLD
405
IS RSSI > REFERENCE?
NO
YES
407
DECREASE POWER
MAINTAIN POWER
INCREASE POWER
TX POWER CHANGE REQUIREMENT
408
320

FIG. 4

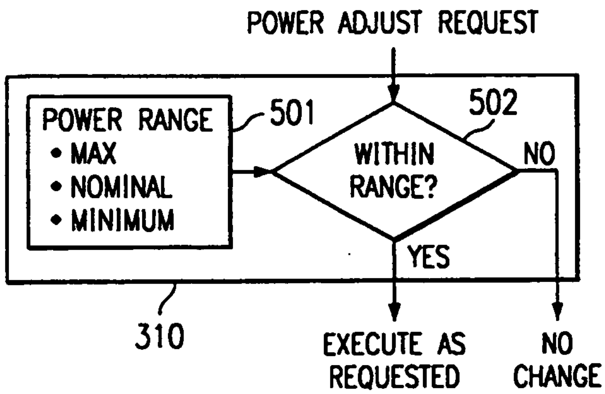
POWER ADJUST REQUEST
POWER RANGE
• MAX
• NOMINAL
• MINIMUM
501
502
WITHIN RANGE?
NO
YES
310
EXECUTE AS REQUESTED
NO CHANGE

FIG. 5

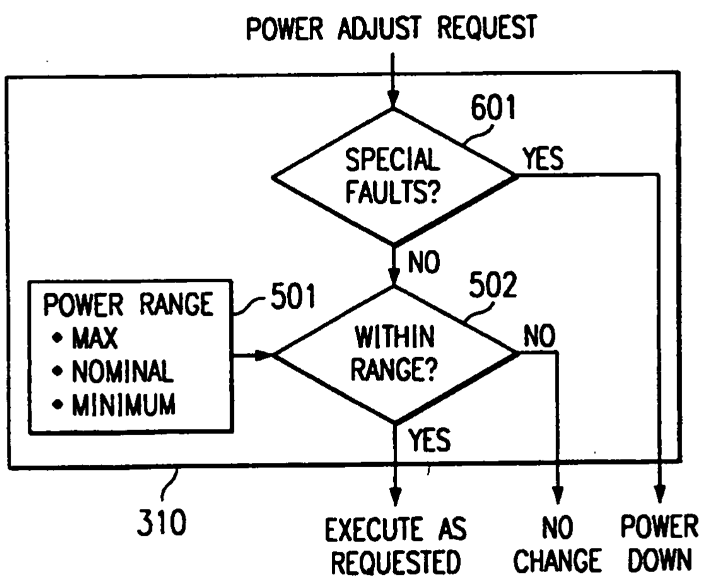
POWER ADJUST REQUEST
601
SPECIAL FAULTS?
YES
NO
POWER RANGE
• MAX
• NOMINAL
• MINIMUM
501
502
WITHIN RANGE?
NO
YES
310
EXECUTE AS REQUESTED
NO CHANGE
POWER DOWN

FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/22251

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/005

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 548 939 A (NIPPON ELECTRIC CO) 30 June 1993 (1993-06-30)	1,9,10
A	column 1, line 52 -column 2, line 42 column 3, line 11 -column 4, line 39 figures 3-9 ---	11,25, 29,35,43
P,A	WO 98 58461 A (ERICSSON TELEFON AB L M) 23 December 1998 (1998-12-23) page 4, line 23 -page 6, line 11 page 8, line 1 -page 11, line 25 page 13, line 5-25 claims 1,13 figures 3-5 ---	1,11,25, 29,35,43
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 January 2000	21/01/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Yang, Y

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INTERNATIONAL SEARCH REPORT

Inter   nal Application No
PCT/US 99/22251

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 777 653 A (BONNEROT GEORGES ET AL) 11 October 1988 (1988-10-11) column 1, line 49 -column 2, line 9 column 7, line 34 -column 8, line 61 claim 1 figures 2-4 -----	1,11,25, 29,35,43

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INTERNATIONAL SEARCH REPORT

..ormation on patent family members

Inter.. ..al Application No
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